MARKSCHEME

November 2002

CHEMISTRY

Higher Level

Paper 2

16 pages

Subject Details: Chemistry HL Paper 2 Markscheme

General

- Each marking point is usually shown on a separate line or lines.
- Alternative answers are separated by a slash (/) – this means that either answer is acceptable.
- Words underlined are essential for the mark.
- Material in brackets (…) is not needed for the mark.
- The order in which candidates score marks does not matter (unless stated otherwise).
- The use of **OWTTE** in a markscheme (the abbreviation for "or words to that effect") means that if a candidate's answer contains words different to those in the markscheme, but which can be interpreted as having the same meaning, then the mark should be awarded.
- Please remember that many candidates are writing in a second language, and that effective communication is more important than grammatical accuracy.
- In some cases there may be more acceptable ways of scoring marks than the total mark for the question part. In these cases, tick each correct point, and if the total number of ticks is greater than the maximum possible total then write the maximum total followed by **MAX**.
- In some questions an answer to a question part has to be used in later parts. If an error is made in the first part then it should be penalised. However, if the incorrect answer is used correctly in later parts then "follow through" marks can be scored. Show this by writing **ECF** (error carried forward). This situation often occurs in calculations but may do so in other questions.
- Units for quantities should always be given where appropriate. In some cases a mark is available in the markscheme for writing the correct unit. In other cases the markscheme may state that units are to be ignored. Where this is not the case, penalise the omission of units, or the use of incorrect units, once only in the paper, and show this by writing **–1(U)** at the first point at which it occurs.
- Do not penalise candidates for using too many significant figures in answers to calculations, unless the question specifically states the number of significant figures required. If a candidate gives an answer to fewer significant figures than the answer shown in the markscheme, penalise this once only in the paper, and show this by writing **–1(SF)** at the first point at which this occurs.
- If a question specifically asks for the name of a substance, do not award a mark for a correct formula; similarly, if the formula is specifically asked for, do not award a mark for a correct name.
- If a question asks for an equation for a reaction, a balanced symbol equation is usually expected. Do not award a mark for a word equation or an unbalanced equation unless the question specifically asks for this. In some cases, where more complicated equations are to be written, more than one mark may be available for an equation – in these cases follow the instructions in the mark scheme.
- Ignore missing or incorrect state symbols in an equation unless these are specifically asked for in the question.
- Mark positively. Give candidates credit for what they have got correct, rather than penalising them for what they have got wrong.
- If candidates answer a question correctly, but by using a method different from that shown in the markscheme, then award marks; if in doubt consult your Team Leader

SECTION A

1. (a) (i) + means energy absorbed / endothermic / bond breaking
– means energy released / exothermic / bond making **[1]**
Both needed for mark.

(ii) $\ominus$ refers to standard conditions / 298 K / $25^\circ C$ and 1 atm / 101.3 kPa **[1]**

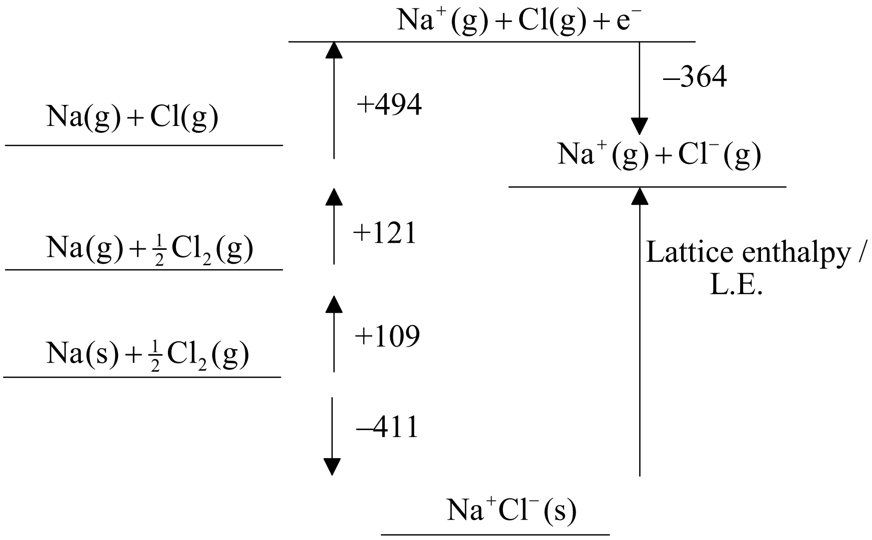
(b)

$\Delta H_f^\ominus(\text{NaCl})$	$\text{Na(s)} + \frac{1}{2}\text{Cl}_2\text{(g)} \rightarrow \text{NaCl(s)}$;	
$\Delta H_a^\ominus(\text{Na})$	$\text{Na(s)} \rightarrow \text{Na(g)}$;	
$\Delta H_a^\ominus(\text{Cl})$	$\frac{1}{2}\text{Cl}_2\text{(g)} \rightarrow \text{Cl(g)}$;	
1st I.E.(Na)	$\text{Na(g)} \rightarrow \text{Na}^+\text{(g)} + \text{e}^-$;	
1st E.Aff.(Cl)	$\text{Cl(g)} + \text{e}^- \rightarrow \text{Cl}^-\text{(g)}$;	**[5]**

State symbols needed for mark, penalise once only if missing.

(c) (i) energy required to change (1 mole of a solid) **ionic** compound / substance / crystal into its **gaseous** ions or vice versa / *OWTTE* **[1]**

(ii)



correct endothermic changes;
correct exothermic changes;
$109 + 121 + 494 - 364 - \text{L.E.} = -411$;
L.E. = +771 kJ mol^{-1}; (*accept* -771 / 771 *kJ mol*$^{-1}$) **[4]**
Units not needed for mark. Allow ECF from diagram.

2. (a) A = electron gun / ionisation chamber / ionizer;
B = electric field / charged plates / potential difference;
C = magnetic field / magnet / electromagnet; ***[3]***

(b) $^{6}\text{Li}^{2+}$;
lowest mass : charge ratio / lowest mass / highest charge; ***[2]***

(c) (i) (existence / mixture of) isotopes / atoms with different number of neutrons; ***[1]***

(ii) $\frac{(79\times24)+(10\times25)+(11\times26)}{100}$
relative atomic mass = 24.32 ***[2]***
Do not accept 24.3 / 24.31.

3. (a) (P constant) $\frac{955}{278}=\frac{V}{298}$; ***[1]***

$V = 1024\ \text{cm}^3$; *(accept* $1020\,cm^3$*)* ***[1]***
no / it will not burst; ***[1]***
Third mark has to follow from correctly calculated volume. Allow for ECF.

(b) increased temperature increases the energy content / kinetic energy of the particles / increases velocity / speed;
particles move about more / spread out;
collide more frequently / more forcefully; ***[2 max]***
Any two correct answers.

4. (a) allows movement of **ions** between the solutions (thus completing the circuit) ***[1]***

(b) (i) $\text{Fe}^{2+} + 2\text{e}^- \rightleftharpoons \text{Fe}\ -0.44\ \text{V}$
$\text{Fe}^{3+} + \text{e}^- \rightleftharpoons \text{Fe}^{2+}\ \ 0.77\ \text{V}$ ***[1]***
Both needed for mark.

$E^{\ominus}$ of cell $= 0.77 + 0.44 = 1.21\ \text{V}$ ***[1]***
Correct answer without working, award ***[2]****.* –1.21 V, *award* ***[1]****.*

(ii) A: $\text{Fe}^{3+} + \text{e}^- \rightarrow \text{Fe}^{2+}$;
B: $\text{Fe} \rightarrow \text{Fe}^{2+} + 2\text{e}^-$; ***[2]***
A and B equations interchanged, award ***[1]****.*

(iii) B to A / Fe to Pt ***[1]***
Allow for ECF.

5. (a) $4X + 3O_2 \rightarrow 2X_2O_3 / 2X + 1\tfrac{1}{2}O_2 \rightarrow X_2O_3$ ***[1]***

(b) mass of oxygen $= 2.199 - 1.239 = 0.960$ g ;

amount (mol) of oxygen $= \dfrac{0.960}{16.00} = 0.060$;

amount (mol) of X $= \tfrac{2}{3} \times 0.060 = 0.040$;

$= 30.97 / 31.0$;

X = P / phosphorus; ***[5]***

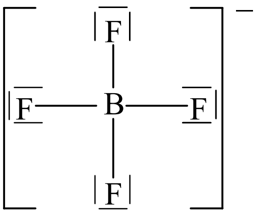
(c)

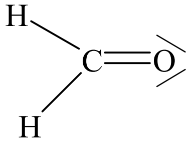
	N	**O**
mass in 100 g	25.9	74.1
amount (mol)	$\dfrac{25.9}{14.01}$	$\dfrac{74.1}{16.00}$;
mole ratio	= 1.85	= 4.63;

formula N_2O_5; ***[3]***

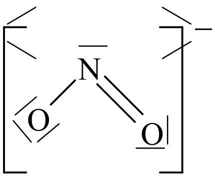
SECTION B

6. (a)





$[\ O=N=O\ ]^+$



[4]

***[1]** for each correct structure.*
*All valence electrons must be shown, penalize **[-1]** once only if omitted.*
*Charges on the ions must be shown, penalize **[-1]** once only if omitted.*

(b)

Species	**Shape**	**Bond angle**	**Explanation**
BF_4^-	tetrahedral	109.5° *accept* 109°	4 negative charge centres and equal repulsion
H_2CO	trigonal planar	120°	3 negative charge centres and equal repulsion
NO_2^+	linear	180°	2 negative charge centres and equal repulsion
NO_2^-	bent / angular / V-shaped	110 – 119°	3 negative charge centres, with greater repulsion by the lone pair

Accept pairs of electrons instead of negative charge centres. If "equal repulsion" is missing, penalize once only.
*Explanation = **[4]**, **[1]** for each species.*
*Shape and bond angle: seven or eight correct **[4]**, five or six correct **[3]**, three or four correct **[2]**, two correct **[1]**.* ***[8 max]***

(c) the mixing / merging / combining of **atomic** orbitals (to form new orbital);

BF_4^-	H_2CO	NO_2^+	NO_2^-	
sp^3	sp^2	sp	sp^2	***[3]***

Four correct = ***[2]****, three/two correct =* ***[1]****.*

(d) covalent bonding / electron sharing;
(single) C — O bond is sigma /σ only;
sigma /σ is formed by end-on overlap of orbitals; *(accept appropriate diagram)*
double C═O bond is sigma /σ and pi / π;
pi / π is formed by (sideways) overlap of parallel p orbitals;
(accept appropriate diagram)
C═O / double bond is shorter than C — O / single;
C═O / double bond is stronger than C — O / single; ***[7]***

(e) (i) delocalization of electrons;
between the carbon and the (two) oxygen atoms / both bonds of equal length; ***[2]***

(ii) 0.128 – 0.136 nm; ***[1]***

7. (a) $2HI(g) \rightleftharpoons H_2(g) + I_2(g)$ ***[2]***

*Award **[1]** for correct equation with* $\rightleftharpoons$ *and **[1]** for correct state symbols. No mark for reversed equation, but can still achieve **[1]** for correct state symbols.*

(b) (i) $K_c = \frac{[H_2][I_2]}{[HI]^2}$;

no units;

ECF for reverse equation ***[2]***

(ii) number of moles HI reacted $= (1 - 0.78) = 0.22$;

therefore number of moles H_2/I_2 formed $= 0.11$;

$K_c = \frac{0.11 \times 0.11}{(0.78)^2}$;

$K_c = 0.02$; *(ECF)* ***[4]***

(c) endothermic; (*ECF - if* $K_c = 0.080$*, then exothermic*)

K_c increases with increasing temperature; *(ECF)*

favours products / equilibrium shifts to the right; *(ECF)* ***[3]***

(d) (i) no change in equilibrium position;

same number of moles of **gas** on both sides of the equation / *OWTTE*; ***[2]***

(ii) equilibrium position moves from left to right;

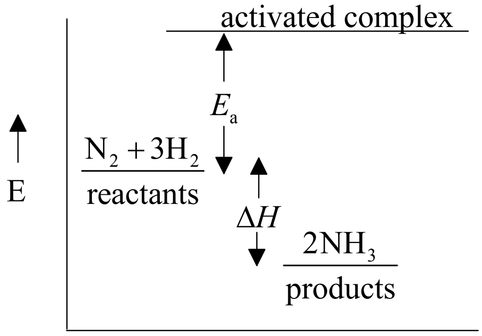
system tries to remove added HI (according to LeChatelier) / *OWTTE*; ***[2]***

(iii) no change in position of equilibrium;

catalyst increases both forward and backward reaction rate (equally) / *OWTTE*; ***[2]***

(e) both HCl(g) and HBr(g) are more weakly dissociated; ***[1]***

(f) (i)



reactants / $N_2 + 3H_2$ higher than products / $2NH_3$;
ΔH / enthalpy change as the difference between reactants and products;
E_a / activation energy as the difference between reactants and intermediate / activated complex / transition state; ***[3]***

(ii) lowers E_a;
provides (lower energy) alternative route / allows for more successful collisions; ***[2]***

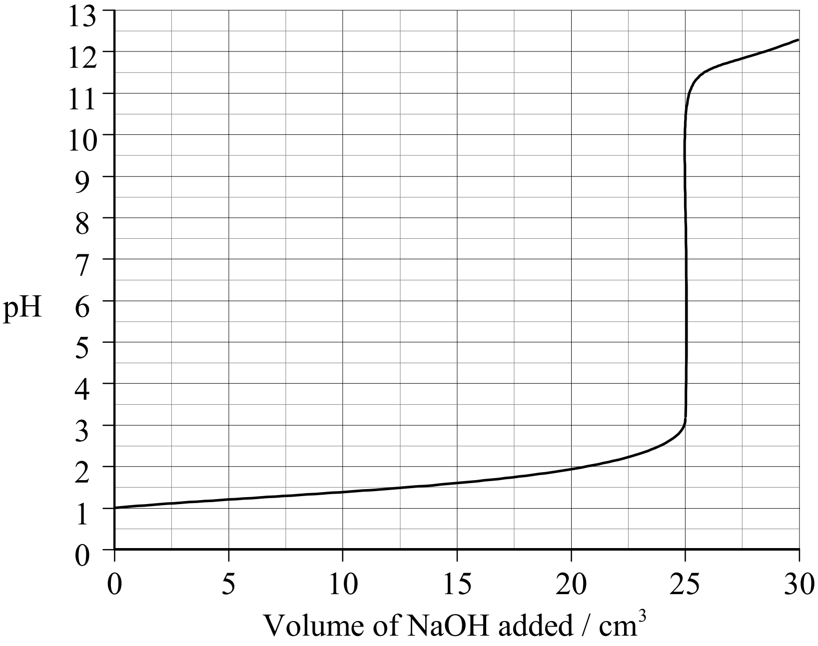
(iii) catalyst is in a different phase / state from the reactants;
reactants are held / adsorbed / held on surface / in sites / active sites (on catalyst); ***[2]***

8. (a) one replaceable hydrogen atom per molecule; *[1]*

(b) (i) 4.8 / 4.9;
value of pH at half-equivalence point; *[2]*

(ii) pK_{in} value / pH range within vertical part of graph;
colour change occurs with addition of small volume of NaOH / end-point of indicator corresponds to equivalence point / colour change occurs as pH changes rapidly near equivalence point; *[2]*

(c) (i)



initial pH = 1; *(accept any value < 3)*
vertical region from about pH 3-10;
final pH = 12-13; *[3]*

(ii) *similarities*
final pH = 12 / same in both because NaOH used;
same equivalence point / 25 cm^3 alkali needed;

differences
initial pH = 1 because $[H^+] = 0.10\ \text{mol dm}^{-3}$ / HCl is strong;
vertical region longer; *[4]*

(d) adding $H^+(aq)$ shifts equilibrium to the left so HIn colour is seen;
adding $OH^-(aq)$ shifts equilibrium to the right so In^- colour is seen; *[2]*

(e) (i) a solution that resists change in pH / whose pH changes slightly;
when a **small** amount of (strong) base or acid is added;

buffer contains (both) a weak acid (HA) and its conjugate base (A^-) / weak base and its conjugate acid / $HA(aq) \rightleftharpoons H^+(aq) + A^-(aq)$;

if H^+ added, these will react with base of the buffer / H^+ is removed as they combine with A^- / equilibrium shifts to the left;

so little change in [HA] and $[A^-]$ / H^+ little affected / strong acid H^+ replaced by weak acid HA; ***[5]***

(ii) sodium benzoate $= C_6H_5COONa$
1 mole $= (6\times12)+(5\times1)+12+(2\times16)+23 = 144$ g;
7.2 g sodium benzoate $= \frac{7.2}{144} = 0.05$ moles;
assume that all of the anion concentration comes from the salt only (as that from the acid is too small to consider) / assume that the ionization of the acid is so small it can be ignored / temperature is 298 K;

therefore $6.3\times10^{-5} = \dfrac{[H^+(aq)]\times0.05}{0.02}$;

$[H^+(aq)] = 2.52\times10^{-5}\,\text{mol dm}^{-3}$; *(accept 2.5×10^{-5} mol dm^{-3})*
pH $= -\log[H^+(aq)] = 4.60$; *(accept 4.6)* ***[6]***

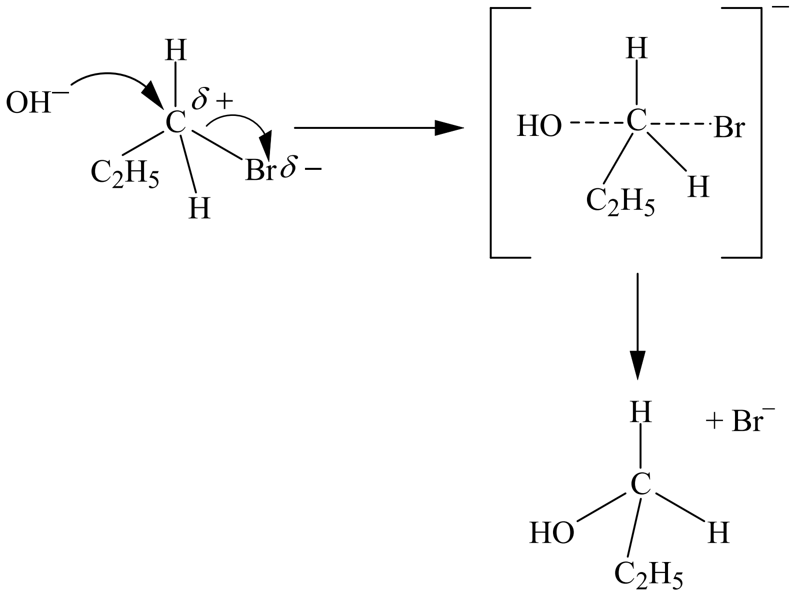
9. (a) (i) no polar bonds / little polarity in C—H bond;
high C—C and C—H bond energies; ***[2]***

(ii) free radical;
homolytic; ***[2]***

(iii) $CH_3CH_2CH_3 = 3:1$; *(accept 6:2)*
$CH_3CH_2CH_2Br = 3:2:2$;
$CH_3CHBrCH_3 = 6:1$ ***[3]***

(b) (i) substitution means replacement of one atom / group in a molecule by another;
nucleophiles are reagents that have non-bonding pairs of electrons;
2 means bimolecular / number of particles in the rate-determining step / *OWTTE*; ***[3]***

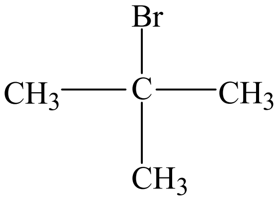
(ii) $CH_3CH_2CH_2Br + OH^- \rightarrow CH_3CH_2CH_2OH + BR^-$
(accept molecular equation and one based on C_3H_7Br)



attack by OH^- on correct carbon;
C — Br arrow correct;
correct intermediate (--- and charge);
structure of product; ***[5]***

(c) (i) primary = 2 × H atoms, 1 alkyl group;
secondary = 1 × H atom, 2 alkyl groups; ***[2]***

(ii) *e.g.*



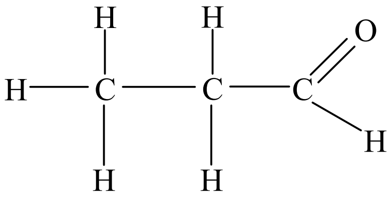
[1]

Accept any suitable answer. Allow R in place of specific alkyl groups.

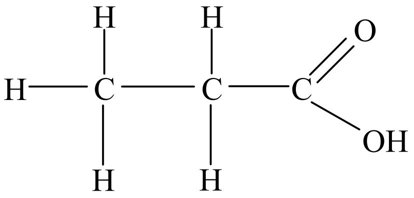
(iii) S_N1 ***[1]***

(d) (i) **acidified** (potassium) manganate(VII) / permanganate / potassium dichromate(VI);
purple to colourless / orange to green; ***[2]***

(ii)



compound X



compound Y ***[2]***

(iii) O — H / hydroxyl bond in acids is more polar because of the (electron-withdrawing) C ═ O group / carbonyl O attracts electrons to itself;
$RCOO^-$ is more stable than RO^- (because of delocalization); ***[2]***